(B) IN THE SPECIFICATION:

Please amend the following indicated paragraphs as shown.

[0006] Internal combustion engines operate as relatively low compression pumps. A diesel may generate approximately a 25 to 1 compression ratio ~~ration~~, meaning that air drawn into the cylinder at close to ambient pressure is compressed to no greater than about 375 psi. In practice only about 300 psi is achieved due to a partial vacuum in the intake manifold and frictional losses. Absent some modification of a cylinder to operate as a higher compression pump, which complicates the engine and may compromise its performance, the compressed air must be recovered from the exhaust manifold, which entails storage at a still lower pressure.

[0024] Contemporary practice provides for computer based control of many vehicle and engine functions, usually organized by systems. An engine controller **20** is representative of such a computer used to monitor and control the operation of diesel engine **16**. Engine controller **20** times fuel injection to each cylinder **32** by control of a fuel injection controller **48**. A camshaft rotates in synchronous with a crank shaft, which in turn is coupled to the pistons in cylinders **32**. Thus camshaft position is related to the phase of each piston relative to TDC. Fuel injection is timed in relation to the cam phase position, provided by a cam phase (engine position) sensor **42**. Fuel injection is handled by an injector controller **48**. The timing of closing and opening of the intake valve **106** and an exhaust valve **110** are effected by engine controller **20** through valve actuators **124** and **126**, respectively. Engine controller **20** is also used to operate a starter **50**, which may be an air starter using compressed air from a compressed air tank **70**. Where an air starter, or some other device using compressed air at the request of engine control module **20** is used, the engine control module is connected to control a solenoid **87** for positioning a valve **85**. Air valve

85 connects compressed air tank **70** to the device, here an air starter **50**, or as described hereinafter, a drive train ~~torque output~~ booster. The pistons of an engine are connected to a rotatable crankshaft (not shown) which is in turn connected to an output shaft and transmission which continue to move the pistons absent fuel flow to the cylinders, as long as the vehicle retains momentum.

[0029] Retention of air pumped from cylinder **32** is controlled by opening and closing shutter valve **34**. A control solenoid **40**, under the control of engine controller **20**, positions shutter valve **34**. When shutter valve **34** is closed, and fuel cut off from cylinder **32**, air is pumped from cylinder **32** during an up stroke into fluidic or pneumatic amplifier **83.** Pneumatic amplifier draws air from the environment through an intake **183**, compresses the air and exhausts the compressed air through a check valve **120** into a high pressure air tank **70**. Fluid amplifier **83** should have a pressure gain of about 20 to 1 and thus be able to deliver air to compressed air tank at pressures in excess of 2000 psi or twenty times the expected pressure of air from cylinder **32**. Shutter valve **34** also operates to release air from the input side of pneumatic amplifier **83** upon opening, which can occur after a brief delay or during engine compression braking or only after pumping is discontinued, as may be preferred for split mode operation. Fluid amplifier **83** could in theory be run from combustion byproduct ~~by product~~ exhaust gas from cylinder **32** at substantially higher pressures, however, such an arrangement would substantially increase back pressure from the exhaust system and thereby reduce the efficiency of the engine. The 2000 psi pressure level is chosen as the contemporary practical economic limit for a motor vehicle compressed air storage system. A higher pressure could be used given progress in seals and tank strength at affordable prices for a mass produced vehicle.

[0031] Finding the preferred periods for operation of the air compression system **18** also requires determining engine load or some other related factor indicative of spare engine capacity. If engine load is low, or better still negative, air compression system **18** can be run at little penalty, and more usually allows energy to be recaptured. Periods of engine compression braking are an ideal opportunity for air compression system **18** operation. Body controller **30** estimates engine load from engine speed, derived from the output of the engine (or cam phase) position sensor **42** and the fuel flow output which are passed to it from engine control module **20**. Body controller **30** also receives inputs, either directly or from other system controllers, which indicate the status or condition of an accelerator pedal/torque request input **54**, a starter button **56**, an ignition switch **58**, a brake pedal position switch **52** ~~**58**~~ and a vehicle speed indication source **59**, all of which may be used to determine other opportunities to initiate air pumping or the need to use air. Under cruising conditions where air tank **70** is fully pressurized, and no demands for air power occur, body controller **30** may determine leakage rates for air tank **70** from periodic sampling of readings from pressure sensor **91**.

[0032] A preferred embodiment of the invention will now be described with reference particularly to **Figs. 3A-D** where a schematic of the pneumatic amplifier **83** and shutter valve **34** are illustrated. Pneumatic amplifier **83** comprises an exhaust chamber **112** which functions as a pneumatic amplifier input chamber. Exhaust chamber **112** is exposed to a working surface **308** of a shuttle piston **304**. Shuttle piston **304** is positioned between chamber **112** and pumping chamber **320**. Shuttle piston **304** is mounted to reciprocate in the directions indicated by the double headed arrow "**C**" allowing air in a pumping chamber **320** to be compressed. A working surface **310** of piston **304** ~~**312**~~ is exposed to pumping chamber **320**. Working surface **308** has approximately 20 times the exposed surface area of working surface **310** meaning that the pressure in pumping chamber **320** balances the pressure in chamber **302** when it is about 20 times as great, less the rebound force

generated by a compression spring **312**. Spring **312** is disposed to urge shuttle piston **304** in the direction "**D**" up to a limit of the shuttle piston's travel. An intake **183** is provided to the pumping chamber **320**, which admits air to the chamber through a one way check valve **314**. The air drawn into the chamber is preferably dried ambient air. The spring constant of compression spring **312** is selected to substantially prevent movement of shuttle piston **304** during the relatively low transient pressures occurring during the exhaust of combustion gases.

[0033] Shutter valve **34** is located in the wall of exhaust chamber **112** and is positioned to control pressurization of the chamber and operation of fluidic amplifier **83**. Exhaust chamber **112** should be made as small as practical to minimize the pressure drop occurring in gas exhausted from cylinder **32** when shutter valve **34** is closed. As illustrated in **Fig. 3A**, exhaust valve **110** ~~**34**~~ is in its opened position, allowing combustion byproducts ~~by-products~~ to escape from cylinder **32**. With exhaust valve **110** ~~valves 32~~ and shutter valve **34** open, reciprocating piston **102** can force exhaust gas from cylinder **32** through the opened exhaust valve **110** as indicated by arrow "**A**" into cylinder exhaust chamber **112** and out of exhaust chamber **112** through shutter valve **34** as indicated by the arrow "**B**" to an exhaust manifold **17**.

[0035] In **Fig. 3C** a pumping stroke of shuttle piston **304** has completed. Fluid amplifier **83** may be operated without drawing fresh air with each cycle into cylinder **32**. Once a charge of air is drawn into cylinder **32**, valves **106** and **34** are kept closed, and valve **110** left open. For subsequent pumping steps, as piston **104** moves downwardly, air is drawn from chamber **112** through exhaust valve **110** back into cylinder **32**, pulling shuttle piston **304** back into chamber **302**, and thereby drawing air in pumping chamber **320** by a now open check valve **314** as indicated by the arrow "**I**". Piston **102** reciprocates in cylinder **32** resulting in the same charge of air being forced in and out of exhaust chamber **112**. Using

this operational sequence it may be possible to eliminate compression spring **312**, simplifying pneumatic amplifier **83**. The effectiveness of such an arrangement will depend upon the quality of the seal formed by shutter valve **34** and some leakage from exhaust chamber **112** is to be expected. Pumping in this manner may require pressure monitoring in chamber **112** and occasionally opening intake valve **106** may be done to replenish the charge. A pressurized first stage system might be employed where, rather than drawing a fresh air charge, pumping begins with a charge of combustion by product from cylinder **32**. Again the intake valve **106** and shutter valve **34** remain closed and valve **110** would remain open while piston **102** reciprocates. Pumping with valve **106** held closed and valve **110** held open is preferably employed when the engine is under a positive load and it is undesirable that pumping mimic a compression brake or draw air from the intake manifold and thus divert it from the firing cylinders.

[0037] Referring now to **Figs. 4**, **5** and **6**, the preferred embodiments of the invention are illustrated. Diesel engine **16** is a simplified representation of the engine described above in connection with **Fig. 2**. The invention is employed to best effect when the various vehicle systems are monitored and data related to operating variables are exchanged between system control processes. This arrangement allows determination of advantageous times to compress air and further determines when there is a demand for air and the capacity to provide it. Compressed air may be applied to vehicle systems such as an air brake system **95** used by a trailer or by an air starter **50** used for starting a diesel engine. Compressed air at the high pressures efficiently recovered by the two stage air compression system described here can also be employed to provide supplemental torque on demand. Utilization of the air also depends upon vehicle operating conditions. In contemporary vehicles major vehicle systems, e.g. the drive train, the engine, the brake system, and so on, are increasingly under the control of system controllers. The system controllers, including an engine controller **20**, a transmission controller **400** ~~**130**~~, an anti-lock brake

system (ABS) controller **99**, a gauge controller **14**, and body controller **30**, communicate with one another over a controller area bus (CAN) **19**, which in the preferred embodiment conforms to the SAE J1939 protocol. CAN bus **19** provides the necessary means to distribute data on vehicle operating conditions and control vehicle operation to support implementation of the invention. CAN networks allow controllers to place non-addressed data on a bus, in standard formats which identify the character and priority of the data and which still other controllers coupled to the bus can be programmed to recognize and operate on.

[0039] In the embodiment of **Fig. 4** a hydrostatic motor **160** provides drive train boost on demand. Hydrostatic motor **160** is used to boost a transmission **150** normally driven by the output shaft **152** from engine **16**. Operation of hydrostatic motor **160** is supported by compressed air from a high pressure air tank **70** ~~**77**~~. Air passes from air tank **70** through a check valve **130** and a valve **85** to hydrostatic motor **170**. Valve **85** is positioned by a solenoid controller in response to a control signal from engine control module **20**. Hydrostatic motor **160** directly boosts transmission **150** to meet part of the torque demand received by the engine controller **20** from body controller **30**, which in turn determines torque demand from the position of an accelerator pedal **54** and torque availability for the engine by subtracting a load estimate from engine capacity (stored in look up tables). Engine controller **20** allocates the response between the hydrostatic motor **160** and engine **16** as a function of engine rpms (determined from cam phase sensor **42**), the availability of compressed air in air tank **70**, provided by a pressure sensor **91** through body controller **30**, and vehicle speed. Engine **16** has a torque output curve as a function in engine rpm's and load which is low at low rpm's and climbs to a peak as rpm's increase. Supplemental torque is of greatest value for taking off from a standing start where no gear choice is available allowing for operation of the engine in an advantageous portion of the engine torque curve. Boost from hydrostatic motor **160** may also be used to limit loading on output

shaft **152** from engine **16** to transmission **150**, allowing the use of a lower weight crankshaft. Vehicles equipped with on board estimation of vehicle load can advantageously adjust the amount of boost to provide the desired acceleration while limiting the load on output shaft **52**. Reducing torque loads on diesel engines also reduces piston blow-by, extending engine oil life and reducing particulate emissions. Exhaust from exhaust manifold **17** is handled conventionally being routed through an exhaust turbine **300** for a turbo-supercharger. Boost is tapered off as engine speed increases and more engine torque becomes available by progressively restricting flow through valve **85**.